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Occurrence of Exotic Fishes in Texas Waters

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OCCURRENCE OF EXOTIC FISHES IN TEXAS WATERS

by Clark Hubbs*

ABSTRACT

Many of the fishes currently inhabiting Texas freshwaters are not native to that location. This influx of exotic fishes is equivalent to about 20 percent of the original freshwater fish fauna.

INTRODUCTION

Many species of fish have been introduced in locations far from their natural range (Lachner et al., 1970); such occurrences may have a variety of impacts. Releases that fail to establish a sustaining population are of minimal ecological importance; however those that succeed must have a negative impact on one or more established occupants of the ecosystem (Hubbs, 1977). Unfortunately, comprehensive studies on the relative densities of fishes have seldom been made prior to an introduction; therefore it is not possible to provide a detailed assessment of the impact of such releases.

Although many authors have endeavored to distinguish between intracontinental (= Transcontinental) and intercontinental (= Exotic) introductions (Stroud, 1975), this artificial concept is of legal importance only. There is no rational ecological reason to create such an artificial dichotomy. A fish moved outside its natural range is less likely to face the population control mechanisms that prevailed in its natural range. Consequently, in this paper I consider any fish out of its natural range to be exotic.

Fish may be transported to a different location for a variety of purposes, herein grouped into four major categories: (1) *bait releases*—small bait fishes, most recently euryhaline species, transported to inland localities; (2) *aquarium releases*—small tropical or subtropical fishes moved to the north; (3) *aquacultural releases*—extracontinental introductions, primarily for human consumption, and (4) *sport-fish releases* for recreational use. The first two categories are commonly without intent to supplement the fauna, but the last two typically involve intent.

The literature on introduced fishes in Texas is extensive but has not been summarized. A quick survey demonstrates that more than 20 percent of the freshwater fish fauna (at least 31 of 144 species) has been moved by man more than 100 km in the past century. The magnitude of these "migrations" vastly exceeds that which has occurred in any preceding comparable time interval. I have chosen 100 km as the minimal distance of movement merely to restrict the discussion; however it is worthwhile to note that the transport of one fish species, *Gambusia affinis,* less than 100 meters has had serious consequences (Hubbs and Broderick, 1963; Hubbs and Williams, 1977).

The original range and extent of introduction of fish species in Texas follows.

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BAIT RELEASES

Cyprinodon variegatus (Lacepède)

The native range of the sheepshead minnow is the coastal waters of eastern United States and Mexico (Knapp, 1953; Moore, 1968; Eddy, 1969). The report by Treviño-Robinson (1959) of this species in the Rio Grande System upstream as far as tributaries at Falcon Reservoir is the farthest inland record prior to 1960. Subsequently, Stevenson and Buchanan (1973), Kennedy (1977), and Hubbs et al. (1978a) reported established populations of sheepshead minnows in Balmorhea Lake, Leon Creek, and Braunig Reservoir, respectively. The first two introductions also involved hybridization and potential gene flow into the populations of *Cyprinodon elegans* and *Cyprinodon bovinus*, species considered to be endangered (Miller, 1979). Rectification of the Leon Creek problem was very costly and involved extensive efforts (Hubbs et al., 1978a; Hubbs, 1980).

Fundulus grandis (Baird and Girard)

The native range of the gulf killifish is coastal waters (Knapp, 1953; Moore, 1968, Eddy, 1969). Although Lamb (1941), Treviño-Robinson (1959), and Tilton (1961) did not record gulf killifish in their surveys, Hubbs (1962) reported it as consistently present in ditches near Brownsville. Subsequently, established populations have been reported in the Brazos River from Lake Whitney to Lake Brazos, the Pecos River near Pandale (Hillis et al., 1980), Lake Balmorhea, and Lake Colorado City, the last of which was sampled by S. Michael Dean and Gary P. Garrett on 5 October 1979. Hillis et al. (1980) reported a single specimen from Lake Balmorhea. Hillis et al. (1980) also reported a number of specimens obtained from the Rio Grande downstream from Falcon Dam. It is uncertain whether this population is natural or introduced since no natural barriers to migration exist downstream from this dam. The abundance of young through breeding adults in the Pecos River population, sampled 15 March and 5 May 1980, demonstrates that this population is well established.

Lucania parva (Baird)

The native range of the rainwater killifish is coastal waters and the saline segment of the Pecos River (Hubbs and Miller, 1965). The status of the record from San Antonio Springs (Evermann, 1893) is problematic since the fish has not been reported from that locality by other authors. Evermann listed four specimens from San Antonio Springs and noted the difficulty in distinguishing the specimens from *Gambusia patruelis* (=*G. affinis*). Two rainwater killifish catalogued in the United States National Museum of Natural History (46299) and stated to have been collected by B.W. Everman, 2 December 1891, are presumably the remainder of those four specimens. An 1895 accession of fish in the U.S. National Museum more or less corresponds with Evermann's 1891 collections. Several discrepancies exist in numbers of specimens. For example, Evermann and Kendall (1894; presumably based on Evermann's 1891 collections) record *Etheostoma fonticola* from Dickinson Bayou, Harris

County, an anomalous locality record at best. Most critically, the 1895 accession list includes five species: *Pylodictis olivaris, Noturus nocturnus, Ictalurus punctatus, Lepomis punctatus,* and *Lucania parva.* Four of the five are discussed by Evermann (1893) as occurring in San Antonio Springs, the exception being *Lucania parva.* If Evermann had noted such an unusual fish in the field he is unlikely to have written, "These waters seem well adapted to the usual species...". Other than the specimens reported above, rainwater killifish are not known from Texas limestone spring waters. It is unlikely that rainwater killifish of native origin now reside in San Antonio Springs. Three possible solutions to this enigma exist: (1) they were native and have died out; (2) Evermann confused the locality data in the field; or (3) the fish had previously been introduced from the coast, presumably in water kegs carried by travelers on the Indianola-San Antonio Road. I feel alternative (3) is most likely and (1) least likely.

The coastal population is known to occur in low-salinity waters of the Aransas River (Renfro, 1960) and in the Falcon Reservoir tributaries (Treviño-Robinson, 1959). On 19 April 1980 three adult male rainwater killifish in breeding colors were obtained in a minnow trap in Clear Creek, Menard County. Additional material has been obtained by seining and/or minnow traps on many subsequent trips. Approximately 2,000 *Lucania* have now been obtained in Clear Creek. This locality had been extensively sampled by a variety of collecting techniques, including a series of more than 1,000 fish taken by the same technique at the same site. The rainwater killifish captured in 1980 were obtained within 100 meters of the only known population of the endangered *Gambusia heterochir.*

Menidia beryllina (Cope)

The inland silverside has often been considered to be a species different from the Mississippi silverside (*Menidia audens*). Chernoff et al. (1981) show extensive intergradation between the two morphs and propose that they are one species. Consequently, the native range of the inland silversides must be considered to be the combined range of both forms. The *M. beryllina* morph is from coastal waters and the *M. audens* morph is found in the Mississippi Basin. In Texas the latter is considered to be restricted to the Red River Basin (Knapp, 1953; Moore, 1968; Eddy, 1969). A report from Caddo Lake by Bonn and Kemp (1952) is the only certain record of the native *M. audens* morph in Texas; Riggs and Bonn (1959) have shown that the Lake Texoma population is undoubtedly the result of an introduction. That population is the probable source for nearby populations subsequently reported and is also the source of this species in Clear Lake, California (Cook and Moore, 1970). Tilton and White (1964) document the spread of inland silversides into the Colorado River Basin and Hubbs and Echelle (1973) and Hubbs et al. (1977) record the spread throughout the Rio Grande Basin. This species seems well adapted for the artificial lentic environments of reservoirs and, once established, may dominate the inshore (insectivore) community. Inland silversides commonly occur in streams near reservoirs inhabited by dense populations, but abundance and suspected impact diminish rapidly with increasing distance from these impoundments.

Membras martinica (Valenciennes).

The native range of the rough silversides is coastal (Eddy, 1969; Knapp, 1953). Although both authors state that the fish enters fresh water, the absence of the rough silversides among the atherinids listed by Moore (1968) implies that they do so infrequently. The initial occurrence was in Amistad Reservoir where samples have been obtained rarely by the Texas Parks and Wildlife personnel (Henderson, 1971). Additional material has been obtained in night seine hauls from Falcon Reservoir (A. A. Echelle, pers. comm., 1980).

Astyanax mexicanus (Filippi)

The native range of the Mexican tetra in Texas (as *Astyanax fasciatus mexicanus*) is the Nueces-Rio Grande basins and southward (Brown, 1953). This fish (a "shiner") was introduced into the Guadalupe Basin before 1930 and has long been widespread in central Texas. Abundant populations occur in clear spring waters of the Colorado (Edwards, 1977) and Brazos (Edwards, 1980) river basins. In the South Concho headsprings, increases of tetras coincided with decreases of stonerollers (*Campostoma anomalum*) (Hubbs and Hettler, 1959). This latter substitution must involve interactions other than direct competition for food as the stonerollers have a major plant component in their diets and Mexican tetras are not known to eat plants regularly (Edwards, 1976). Riggs and Bonn (1959) report the presence of the Mexican tetra in Lake Texoma (as the result of a bait introduction) but it appears to have become extinct there because recent collections do not contain it. (Patten et al., 1975).

AQUARIUM RELEASES

Poecilia latipinna (Lesueur)

The native range of the sailfin molly in Texas is the Rio Grande flood plain and coastal waters. It has been introduced into the Guadalupe Basin (Brown, 1953) and is reasonably widespread in the Colorado Basin downstream from the Balcones Escarpment (Tilton, 1961). It is probable that sailfin mollies reported from Las Moras Spring (Treviño-Robinson, 1959) and collected there on 11 March 1979 were also introduced.

Poecilia formosa (Girard)

The native Texas range of the Amazon molly certainly includes the lower Rio Grande Valley (Darnell and Abramoff, 1968). It is uncertain whether the populations from the lower Nueces River (Martin, 1964) or those from the King Ranch (taken in April 1966) are native or introduced. There is no doubt as to the origin of the San Marcos population (Drewry et al., 1958); it was derived from fish released from the San Marcos State Fish Hatchery that had originally been obtained from Olmito State Fish Hatchery near Brownsville (Hubbs, 1964). This report was confirmed by Kallman (1962) who demonstrated common clones in the suspected source population as well as in the released population. This population has spread downstream to Martindale and north into the lower part of the Blanco River

(Edwards et al., 1980). A second unquestionably introduced population inhabits Braunig Lake (Hubbs et al., 1978b). This species is also known from the San Antonio River immediately downstream from the city and may have entered this stream from connecting Braunig Lake. The abundance of this species is of special importance because it reproduces gynogenetically (Hubbs, 1964; Kallman, 1962), depending upon males of closely related species to stimulate egg development.

Poecilia reticulata (Peters)

The native range of the guppy is the lesser Antilles and northern South America. It has been introduced widely throughout the world (Rosen and Bailey, 1963); in the United States, guppies have been found in Florida (Courtenay and Robins, 1973) and Nevada (Deacon et al., 1964), as well as in Texas. Hubbs et al. (1978a) reported an established population, obviously of aquarium origin, in stenothermal spring waters in San Antonio. Edwards (1976) reported another population in Waller Creek, Austin, that disappeared following cold winter weather. It is expected that many releases of this common aquarium fish have occurred elsewhere but that most stocks die if they do not have access to warm (usually stenothermal) waters in the winter.

Belonesox belizanus (Kner)

The native range of the pike killifish is the Atlantic lowlands of southeastern Mexico and northern Central America (Rosen and Bailey, 1963). A population was reputed to have been established in Brackenridge Park in San Antonio (Barron, 1964). Hubbs et al. (1978a) were unable to locate any individuals and it is likely that this population no longer exists. The fish, however, has successfully established a population near Miami, Florida (Courtenay and Robins, 1973).

Hypostomus c.f. ***plecostomus*** (Linnaeus)

It is uncertain whether the armored catfish known to have been released into San Antonio headwaters represents this or a related species. Thus, its native range in America cannot be stated in detail. There is no question, however, that the native range of this genus is in tropical South America. The Texas population in San Antonio Springs was first recorded by Barron (1964), and Hubbs et al. (1978a) recorded it as a major component of the fish fauna in the spring run. The same or a similar species has also been established in Florida (Courtenay and Robins, 1973).

Gambusia geiseri (Hubbs and Hubbs)

The largespring gambusia was considered to have a native range essentially restricted to the San Marcos and Comal rivers from their sources to their junctions with the Blanco and Guadalupe rivers, respectively (Hubbs and Springer, 1957). These authors concluded that the scattered populations inhabiting the South Concho River, Devils River, ditches around Balmorhea and the now extinct Comanche and Tunis springs populations were derived from stocking for mosquito control. A similar hypothesis is a reasonable explanation for

the Leon Creek population (Hubbs et al., 1978b). Yet another population of largespring gambusia now occurs in Independence Creek (David Hillis, pers. comm., 1980). This stream had been extensively sampled in 1949 (W.F. Blair, pers. comm., 1980) and *Gambusia affinis* was the only poeciliid obtained. The hypothesized protocol of an introduction into a headspring is parallel to the experiment reported by Hubbs and Springer. *Gambusia* were released into the South Guadalupe River in 1956 where they thrived until a large flood in 1960. Subsequently, none has been found, despite extensive collecting such as that reported by Edwards (1980). Although the flood (or some similar disturbance) may well have eliminated the stocked population, its survival for four years indicates that a stocking of largespring gambusia in a spring environment can easily survive. The similarities between the unique mortality patterns of largespring gambusia males from San Marcos and from the South Concho (Hagen, 1964) suggests a close genetic relationship that can best be explained by a recent derivation of one population from the other. The stocks of largespring gambusia near Comal Springs [e.g., Bear Creek, Comal County (Hubbs and Springer, 1957)] or San Marcos springs near Martindale, Caldwell County (Edwards et al., 1980) are likely to be natural, although one or both may depend upon strays from the well-established natural populations nearby.

AQUACULTURAL RELEASES

Cyprinus carpio (Linnaeus)

Carp were originally imported to North America by the U.S. Fish Commission, an agency that later formed the Bureau of Sport Fisheries and Wildlife and the National Marine Fisheries Service. The initial official releases were in New York in 1877 from stocks that were transported from Germany (Hessel, 1878), but private releases occurred as early as 1831 and established populations were reported by deKay in 1842. By the middle 1880s, carp were spread over most of the United States, but not until the end of the century was it generally recognized that carp might cause more harm than good in the natural waters of the United States (Trautman, 1957). The first releases in Texas seem to have been made in 1882 by R.R. Robertson of the first Texas Fish Commission, a governmental body that was abolished in 1885 largely as a consequence of those releases (Texas Game Fish and Oyster Commission, 1929). Texas may well have been the first state that officially expressed distress about the use of carp in natural waters. Carp now occur in virtually every Texas reservoir and most large, sluggish streams.

The German stocks are usually ascribed to a Chinese origin, transported to Europe before the sixteenth century (Jordan and Evermann, 1902), but Balon (1974) argues that they were derived from populations native to the lower Danube. Regardless of which account is correct, carp were actively cultured in Germany before 1600. These German stocks were the source of the fish brought to the United States.

Carassius auratus (Linnaeus)

The status of goldfish in the United States is in many ways similar to that of the carp. They were widely distributed near the turn of the century.

Whereas carp were derived from stocks raised for food consumption, goldfish were cultured for ornamental purposes. The stocks of goldfish in the United States have a primarily Chinese origin, either directly or through Europe. Goldfish are cultured as ornamental fishes and bait fishes; however, their adult size makes them admirably adapted as a human food source. Goldfish have been collected from many Texas locations. It is likely that many are maintained only by sporadic releases of ornamental aquarium fishes, but disjunct self-perpetuating stocks occur in widely scattered locations in Texas (E. L. Simmons, pers. comm., 1980).

Sarotherodon mossambicus (Peters)

The Mossambica tilapia is native to eastern African rivers (Fryer and Iles, 1972). This species was first recorded in Texas waters by Hubbs (1961), who reported it from the San Antonio and San Marcos rivers. It remains in these two spring runs (Hubbs et al., 1978a), but it is not nearly as abundant as the Rio Grande cichlid (Buchanan, 1971). This species and the blue tilapia have been placed in *Sarotherodon* rather than *Tilapia* by Trewavas (1953). Both species are likely to have been widely released in Texas (and the southern United States as well) and the established populations are in spring runs (*S. Mossambicus*) and primarily thermal reservoirs (*S. aureus*).

Sarotherodon aureus (Steindachner)

The blue tilapia naturally ranges from North Africa to Palestine (Fryer and Iles, 1972). Much of the literature on this fish uses the name *Tilapia nilotica* with which this cichlid has been confused. The first report of a self-sustaining Texas population is that of Noble et al. (1975) in Trinidad Reservoir. That population seems to have died out (Kirk Strawn, pers. comm., 1979) during cold weather when the power plant (producing waste heat) was turned off. In the interim, however, populations became established in Braunig Reservoir (Hubbs et al. 1978a), Lake Nasworthy, Amistad Reservoir (Hubbs, 1976), Falcon Reservoir, Canyon Reservoir, Lake Calaveras, Tradinghouse Creek Reservoir, Lake Creek Reservoir, Lake Colorado City, and Lake Fairfield (R.J. Bounds, pers. comm., 1980). The first two and the last five have thermal generation stations. Falcon Reservoir is sufficiently far south that winter kills are unlikely. Amistad and Canyon Reservoirs are in aquifer discharge zones that may have cold winter temperatures moderated by stenothermal outflows. The widely scattered populations of blue tilapia provide multiple opportunities for selection toward increased cold tolerance which would allow eventual wide distribution of this fish throughout Texas. The northern extent of the natural range of this species is approximately the latitude of the city of Dallas.

Tilapia zilli (Gervais)

In 1978 M. Mangini and Peter Rubec obtained specimens of the redbelly tilapia from the spring-fed waters of San Antonio Zoo (pers. comm., John D. McEachran and R.L. Noble, 1980). These fish were found entirely within zoo waters; however, these waters are derived from springs that flow through mammal exhibit cages and empty into the San Antonio River. These cichlids

seem to be self-perpetuating in this new environment and have free access to the San Antonio River. The native range of this tilapia is western Africa to Palestine.

SPORT-FISH RELEASES

Micropterus dolomieui Lacepède

The native range of the smallmouth bass occupies much of the north and central United States. The southeastern margins are the Ouachita Highlands of southwestern Arkansas and southeastern Oklahoma (Robbins and MacCrimmon, 1974). Their figure implies established populations in the San Marcos and Llano rivers. Both resulted from Texas Parks and Wildlife Department releases, as reported by Hubbs and Peden (1968) for the former locations. Subsequently, numerous smallmouth bass releases have occurred and it is difficult to be certain of natural reproduction at locations with frequent releases. Captured young fish could be that year's released fish or offspring of previous releases. The first clear documentation of successful smallmouth bass reproduction in Texas was that of Edwards (1979), who demonstrated the occurrence of *M. dolomieui* X *M. treculi* hybrids in Canyon Reservoir and in the upper Guadalupe River. As no such artificially produced hybrids have been introduced, the only source is natural reproduction indicating presence of reproductive *M. dolomieui* individuals of at least one sex in that region. The large numbers of young smallmouth bass in the same collections provide convincing evidence that both sexes were reproductive at the same time. The documentation of hybridization also shows a substantial problem of potential genetic swamping of an endemic game fish.

Micropterus salmoides floridanus (Lesueur)

The native range of the Florida subspecies of largemouth bass is Florida, southern South Carolina and Georgia, and southeastern Alabama (Ramsey, 1975). This population freely interbreeds with the northern subspecies of largemouth bass (*M. s. salmoides*). The original stocks of the Florida largemouth released in Texas waters were artificially produced F1 hybrids (= the so-called "superbass"; Baxter, 1972). These fish seem to exhibit heterosis and large individuals recently obtained by anglers from East Texas reservoirs may be F1 hybrids. More recent Texas stockings have involved pure Florida largemouth stocks; these fish seem to grow well in some Texas reservoirs (notably thermal ones) and their offspring are also likely to exhibit heterosis. It will be difficult in future years to ascertain the amount of Florida versus northern largemouth genetic contribution without biochemical analysis of individual fish, for the differences between the two subspecies are not discrete and become blurred in subsequent generations. Moreover, the simplest diagnostic character (lateral-line scale counts) is environmentally plastic (Strawn, 1961) and developmental temperatures could influence this phenotypic attribute more than would the genetics of the fish. It is probable that the growth component resulting from heterozygosity will not be found in future generations. It would be expected that the disruption of genetic homeostasis in largemouth bass

having recombinant genotypes will result in depressed growth rates. Therefore, it may be necessary to introduce Florida largemouth bass continuously to retain heterotic growth. Under those circumstances, disrupted genetic homeostasis may be the rule in largemouth bass populations.

Stizostedion vitreum (Mitchill)

The native range of the walleye extends from southern Canada to northern Arkansas and Kansas (Moore, 1968; Eddy, 1969). Walleyes were stocked in a variety of Texas impoundments in the 1950s, but the first succcessful population was established in 1965 in Lake Merideth (Peer, 1974; Prentice and Clark, 1978; Provine et al., 1978). The source of fish for that release seems to have been Spirit Lake, Iowa. The offspring of that released stock had a warmer range of temperature tolerance than that of another stock obtained from southern Ontario (Hubbs, 1971a). Whether that differential tolerance reflects a difference between the source stocks or adaptation to a southern environment is unresolved. Subsequent stockings using eggs from the introduced population in Lake Merideth and eggs from the natural range have resulted in established populations in Twin Buttes, Bridgeport, Fort Phantom Hill, Greenbelt, and Canyon reservoirs (R. J. Bounds, pers. comm., 1980). I suspect the vast majority of the fish now surviving in those reservoirs are descended from the Lake Merideth stocks.

Morone saxatilis (Walbaum)

The natural range of the striped bass extends from New Brunswick to northwestern Florida (Moore, 1968; Eddy, 1969). This fish has been widely introduced in the United States. The population in the San Francisco Bay area is of long standing. Recently, striped bass have been introduced in Texas reservoirs (Bonn, 1975; Allen, 1976; Leifeste, 1976) as well as those in most central states. The Texas stocks come from many Atlantic coast drainages, but it is probable that the majority of the survivals are South Carolina fish from the Santee-Cooper drainage where this anadromous fish, which normally spends much of its life in marine waters, has established a landlocked population with its normal marine phase spent in freshwater reservoirs (Stevens, 1958). Reproducing Texas populations exist in Lake Texoma, Lake Granbury, Lake Whitney (Mulford, 1980), and perhaps Amistad Reservoir. It is also probable that the striped bass biomass available in Texas reservoirs for sport fishermen is essentially a replacement for white bass *(M. chrysops)* biomass.

Morone chrysops (Rafinesque)

The native range of the white bass is extremely difficult to ascertain. Eddy (1969) and Moore (1968) list it as inhabiting the Great Lakes region and extending south to Texas. Knapp (1953) reports it to be an abundant species in the larger Texas lakes and reservoirs. Certainly, white bass are a major component of the fish fauna of most Texas reservoirs and that presence is of long standing. I know of no Texas records of white bass prior to 1900. In their summary of all prior studies from Texas and adjacent waters, Evermann and Kendall (1894) record white bass only from the Red River

at Fulton (i.e., 30 km NW Texarkana), Arkansas. Presumably, that record reflects a population in the Red River that occurred naturally in northeastern Texas. With the possible exception of the Sabine and Neches drainages, other Texas populations are undoubtedly introduced. Bonn (1972) argues that Caddo Lake had the only natural white bass populations in Texas. Two other fish now common in many Texas locations (*Lepomis auritus* and *L. microlophus*) are not reported by Evermann and Kendall (1894) to occur in Texas and must also be considered to have been introduced into Texas waters.

Salmo gairdneri (Richardson)

The rainbow trout is native to waters on the western slope of the continental divide (Moore, 1968; Eddy, 1969). An established population exists in McKittrick Canyon in the Guadalupe Mountains (Knapp, 1953). Rainbow trout have been stocked in a variety of other Texas waters but none has been shown to establish breeding populations. The most successful populations seem to be in stenothermal spring waters on the Edwards Plateau and hypolimnion tail waters downstream from stratified reservoirs such as Canyon and Possum Kingdom (Forshage and Butler, 1973; Garcia, 1977). The stocked fish often thrive but do not reproduce. Lack of reproduction may involve the absence of extremely cold waters in winter that may be essential for the maturation of their gametes.

Ambloplites rupestris (Rafinesque)

The rock bass is native to the North Central United States. An introduced population thrives in the San Marcos area (Brown, 1953). Rock bass have also been recorded from Comal Springs and a spring-fed tributary to Johnson Creek adjacent to the Mountain Home State Fish Hatchery, now Experimental Fish Station (Kuehne, 1955). The Comal Springs population may have been exterminated during a rotenone renovation program (Kuehne, 1955). Nevertheless, rock bass now occur in the Guadalupe River below Canyon Reservoir. The source of the thriving San Marcos population was Iowa (Brown, 1953), not the nearby Louisiana or Arkansas stocks. This is parallel to circumstances in Blue Springs, New Mexico (Cashner and Suttkus, 1978). These authors also reported rock bass as occurring in unspecified Frio River headwaters.

Cichlasoma cyanoguttatum (Baird and Girard)

The native range of the Rio Grande cichlid in Texas is the Rio Grande-Nueces basins. This fish was introduced into the Guadalupe Basin by the federal fish cultural station before 1940 (Brown, 1953) and is now abundant in the San Marcos (Buchanan, 1971), Colorado, and Brazos river basins (Edwards, 1980). As appears to be the case with the Rio Grande tetra, this cichlid may be approaching the northern edge of its potential range because the species tends to concentrate in stenothermal spring environments that do not freeze in winter, and Hubbs (1951) reported extensive mortality in the Colorado River during a period of unusually cold weather.

DISCUSSION

Aquatic ecosystems are impacted by a large variety of cultural activities. One of the most pervasive and long-range effects is that of the release of exotic aquatic organisms. The survival of exotics is often enhanced by other perturbations such as impoundment (e.g., *Menidia beryllina* in reservoirs, *Sarotherodon aureus* in thermal cooling ponds). These bodies of water are artificial in Texas, and the environments themselves have had serious detrimental impacts on the native fishes of the plains states (Hubbs and Pigg, 1976). If the exotics could be contained within these restricted environments, minimal additional problems would develop (Thompson et al., 1977). Unfortunately, most reservoir fishes are not reservoir-restricted and have additional impacts for considerable distances both upstream and downstream.

Some of the releases (*Salmo gairdneri, Cyprinus carpio,* and *Poecilia latipinna*) precede inventories of fish abundance in Texas waters; others are very recent and the potential impact is not yet fully developed. For example, carp were released in the northeastern United States nearly 20 years before the problems associated with their abundance were documented (Trautman, 1957). Thus, fishes established in Texas since 1960 may not yet have fully developed adaptations to Texas environmental conditions.

The above listing of fishes introduced throughout Texas is incomplete. There is an established population of *Esox lucius* (northern pike) in Greenbelt Reservoir in the panhandle and a record of *Perca flavescens* (yellow perch) in the Rio Grande downstream from Elephant Butte Reservoir (Hubbs, 1955) where it was stocked by New Mexico fisheries. Neither of these game fish species is native to Texas waters. Similarily, the presence of *Notemigonus crysoleucas* (golden shiner) in Big Aguja Canyon, Jeff Davis County, and Big Fielder Draw, Val Verde County (both obtained in May 1980) reflects a western bait dispersal of this typically East Texas species. The records of *Pimephales promelas* (fathead minnow) from the southern Edwards Plateau also are the probable result of bait escapes; Evermann and Kendall (1894) did not record this commonly used bait minnow from the region. The occurrence of *Pimephales vigilax* (bullhead minnow) from the Rio Grande near El Paso (Hubbs et al., 1977) and *Fundulus zebrinus* (plains killifish) from the Rio Grande in Big Bend National Park (Hubbs and Wauer, 1973) are documented "migrations" in historical time. The release of *Notropis venustus* into the Pecos River at Pandale (R. Everett, pers. comm.) is a transport of less than 100 km but represents an artificial migration from the Rio Grande. This list may soon be augmented since *Culaea inconstans* (brook stickleback) has been observed in numerous bait minnow tanks. This fish is unlikely to be used as bait and may frequently be discarded live into Texas waters by fishermen at the end of the day. Similarly, *Xiphophorus maculatus* (southern platyfish) is extensively used as an ornamental aquarium fish and might be emptied into natural waters, establishing breeding populations, as has happened in Nevada (Deacon et al., 1964). Several other aquarium fishes (mostly cichlids and poeciliids) have great potential for release and establishment of breeding populations.

Several other intentional releases either have taken place or are in their late planning phases; any of these could establish breeding populations. This list includes *Lates nilotica,* the Nile perch (Pritchard, 1972), *Cichla timensis,* the peacock bass, or a closely related species (Chew, 1975), and *Ctenopharyngodon idella,* the grass carp. The latter is the most likely to survive; a breeding population of this Asiatic fish exists in the Mississippi River (Conner, Gallagher, and Chatry, 1980).

The population of *Minytrema melanops* (spotted sucker) in the Llano River may represent an introduction; but it is also possible that the records reflect a naturally disjunct population. Similarly, the recent record of *Cyprinodon rubrofluviatilis* from the Colorado River drainage (Echelle et al., 1977) is a possible introduction, but insufficient negative data are available prior to their discovery. Other marine or euryhaline fish are frequently stocked in Texas reservoirs. The probability that these marine species may establish breeding populations is low except in West Texas reservoirs with saline inflows. The most extensively used fishes in this category include *Sciaenops ocellatus* (red drum), *Paralichthys lethostigma* (southern flounder), and *Cynoscion nebulosus* (spotted seatrout) (Cox, 1972; Hiller, 1976).

The major impact of the release of exotics may well occur in arid parts of Texas where species diversity is low (Hubbs, 1957). Minckley and Deacon (1968) have reported that release of exotics is a major reason for the reduction in abundance of the native fishes in the American Southwest. The western half of Texas faces similar problems. Inventories of species abundance in Arizona (Miller, 1961), New Mexico (La Bounty and Minckley, 1973), and northern Mexico (Contreras-Balderas, 1978) provide ample evidence that successful introductions replace native fishes almost on a one-to-one basis. The report by Smith (1979) establishing that exotic species virtually equaled extinctions in Illinois suggests the problem is not limited to xeric regions.

The number of fishes in novel Texas waters is extensive. Of the documented examples, 10 are bait releases (6 of the 7 discussed individually [the exception is *Belonesox belizanus*] plus *Notemigonus crysoleucas, Pimephales vigilax,* and *P. promelas*); 6 are aquarium releases (all discussed individually, but the release of *Gambusia geiseri* undoubtedly is due to public health agencies); 4 are aquacultural releases (all discussed individually); and 11 are sport-fish releases (7 of the 8 discussed [the exception is *Micropterus salmoides floridanus,* excluded only because it is not a distinct species] plus *Lepomis auritus, L. microlophus, Perca flavescens,* and *Esox lucius*). The total number of fishes in Texas with established populations 100+ kilometers beyond their natural ranges is at least 31. This number is impressive, especially when contrasted with the known 145 species that have established breeding populations in inland Texas waters prior to 1850 (217 species listed by Hubbs [1976] minus 57 coastal species, 14 not native to Texas, and one synonymized species). Although only 15 species have been added to the Texas fish fauna, 16 more are also novel members of one or more Texas ecosystems that lack natural population control mechanisms for the novel fish.

Only one fish, *Notropis simus* (and perhaps a close relative, *N. orca*), seems to have been eliminated from the Texas fish fauna, although several (*Scaphirhynchus platyrynchus, Dionda diaboli,* and *Erimyzon succetta*)

have had substantial range reductions within Texas waters that may be associated with the presence of exotic fishes.

Numerically the major exotics are in the bait and sport-fish categories with each about equal to the combined aquarium and aquacultural contributions. Numerical comparisons overlook degrees of impact; several of the exotics (*Membras martinica, Poecilia reticulata, Perca flavescens, Esox lucius*) have limited Texas distributions. Some (*Menidia beryllina, Stizostedion vitreum, Sarotherodon aureus*) are almost exclusively in artificial environments and others (*Morone saxatilis, Poecilia formosa*) may primarily impact previously released exotics. I believe the seven exotics with the most potential for environmental damage are: *Cyprinodon variegatus, Astyanax mexicanus, Poecilia latipinna, Cyprinus carpio, Sarotherodon mossambicus, Cichlasoma cyanoguttatum,* and *Micropterus dolomieui.* (If *S. aureus* were to escape the confines of its present restriction to artificial environments it would also be on this list.) The high damage potential list is composed of 2 bait releases, 1 aquarium release, 2 aquacultural releases, and 2 sport-fish releases. Thus, 2 of 4 aquacultural release fishes have a high environmental damage potential and two more aquacultural fishes (*Sarotherodon aureus* and *Ctenopharyngodon idella*) might well be added to the high damage listing before the end of this decade if self-reproducing populations should be established.

Regardless of the amount of the niche space and/or the geographic region involved, each movement of an organism to a novel location has a negative impact on one or more occupants of that environment. Because of the numerous other potential negative impacts to our native biota, responsible biologists should minimize any activities that would exacerbate problems. Although ignorance is no excuse, I am most troubled by intentional releases advocated by biologists who should understand the basic principles of ecosystems dynamics.

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